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ORIGINAL RESEARCH ARTICLE

Efficacy of natural products and biorationals against yellow mite, *Polyphagotarsonemus latus* (Banks) (Acari : Tarsonemidae) infesting hydroponic Capsicum under protected cultivation

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Abstract
Phytophagous mites especially yellow mite, *Polyphagotarsonemus latus* (Banks) and two-spotted spider mite, *Tetranychus urticae* Koch cause major problems in the cultivation of capsicum or green pepper under protected conditions resulting in significant yield losses. The objective of this study was to evaluate the efficacy of different biorationals and natural products against yellow mite, *P.latus,* infesting capsicum grown in hydroponic system in polyhouse conditions during 2019. The natural products and plant extracts were prepared indigeneously. Results revealed that among all the treatments, pepper extract @ 30ml/l followed by both *Brahamastra* and *Agniastra* at the highest doses of 50ml/l caused maximum mortality of mites. Even the PAU home made neem extract and *Pongamia* extract both @ 12ml/l were found more effective as compared to the *Dherek* extract. The bioagent, anthocorid bug, *Blaptostethus pallescens* @ 10 nymphs per plant reduced the mite population after two releases at weekly interval. These natural products and biorationals can be incorporated in integrated mite management programmes under protected cultivation.

Keywords Capsicum · Biorationals · Natural products · Yellow mite · Management

Introduction

Capsicum (*Capsicum annuum* var. *frutescens*) (Family-Solanaceae), also known as green pepper, is one of the most popular, nutritious and highly remunerative vegetable crop grown throughout the world. Pepper is an important agricultural crop, not only because of its economic importance, but also for the nutritional value of its fruits, as they are an excellent source of natural colors and antioxidant compounds and the pepper fruit is considered an important source of bioactive nutrients, such as carotenoids, vitamin C and phenolic compounds (Navarro et al. 2006). Capsicum is commercially grown under white shade nets of 30-40 per cent shading for producing high-quality fruit, avoiding sunburns, and saving on irrigation water. The production of crops under protected conditions, whether in climate-controlled greenhouses and glasshouses or covered by plastic sheets or 'insect-proof screening' ('tunnels') with little or no climate control, is increasing worldwide. In recent years, pepper has also been grown under hydroponic system or soil-less medium and is gaining popularity among the farmers.

In India, capsicum or green pepper is intensively cultivated in Karnataka, Maharashtra, Tamil Nadu, Punjab, Himachal Pradesh and hilly areas of Uttar Pradesh. Pepper cultivation under protected condition is gaining popularity especially coloured hybrids in peri-urban production system because of easy access to urban markets. Various biotic, abiotic and physiological factors are the main constraints encountered by the farmers in getting higher productivity and good quality produce. Unlike many of the field problems, insect and pest problems are peculiar to green house cultivation with sucking pests especially mites posing a serious problem under protected condition. They multiply in large numbers under controlled temperature and relative humidity there by leading to significant crop loss (Sorensen 2005).

Phytophagous mites especially yellow mite, *Polyphagotarsonemus latus* (Banks) and two-spotted spider mite,

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Tetranychus urticae Koch cause major problems in its cultivation under protected conditions resulting in significant yield losses (Attia et al. 2013) and in Indian conditions too, under poly-net and nethouses, mites cause major problems and hampers crop productivity (Dhooria 2016).

Consumer's demand for healthy and 'green' produce is ever-increasing but farmers generally rely on chemicals for pest control, and the indiscriminate use of these chemicals leads to adverse effects like residues in the fruits, pest resurgence and destruction of natural enemies which suggest the need to develop alternative management strategies (Dhooria 2016). Neem oils and extracts are considered as the best option for the insect pest management program in vegetables because they are safe for beneficial organisms, target-specific, and compatible for biological control agents (Tang et al. 2002). Dougoud et al. (2019) have reviewed the efficacy of homemade botanical insecticides based on traditional knowledge and reported that *Azadirachta indica* A. Jussand (Family – Meliaceae) has excellent insecticidal properties due to the presence of limonoids which interfere with various physiological processes and chemical pathways thereby offering feeding deterrence and toxic effects to the insect-pests. In India, organic farming based on natural products and indigenous approaches has been practiced since many years and is now forming an important component of modern farming practices too. The organic farming system has cow as a key component and has gained importance among farmers mainly due to benefits of soil fertility, soil health and sustainable productivity (Ram and Pathak 2016). The natural preparations containing byproducts of cow are quite effective in enhancing crop productivity and at the same time suppressing the growth of many insect and mite pests (Phukan et al. 2017). In recent years, plant extracts and botanical pesticides have showed great importance in agricultural fields due to their cheap and low expenses, with no residual effects, environmentally friendly, and highly toxic against major pests such as thrips, aphids, jassids, whitefly, and mites. Botanicals like neem oil, *Mohua* oil, *Pongamia* oil, NSKE, neem cake based biopesticides, marigold, mentha, seed extracts of jatropha, black pepper, custard apple, turmeric and biorationals like neem-garlic and chilli-garlic aqueous extracts both @ 2% were found to be effective against many phytophagous mites (Gupta 2012). Neem oils and extracts are considered as the best option for the insect pest management program in vegetables because they are safe for beneficial organisms, target-specific, and compatible for biological control agents. The efficacy of homemade botanical insecticides based on traditional knowledge has been reviewed and reported that *A. indica* and *Melia azadirachta* (Family – Meliaceae) have excellent insecticidal properties due to the presence of limonoids which interfere with various physiological processes and act in feeding deterrence and toxic effects to the insect-pests (El-Wakeil 2013). Similarly, the efficacy of plant derivatives like garlic bulb extract @ 10 %, *Pongamia* oil @ 3 % and neem oil @ 3 % against *T. urticae* on rose in Tamil nadu has also been reported (Ramaraju and Bhullar 2013;Raghavendra et al. 2017). Spiromesifen is a reduced risk insecticide from a novel chemical class of Ketoenols with titronic acid derivative compounds. The pesticidal mode of action is inhibition of lipid biosynthesis, especially triglycerides and free fatty acids (Bretschneider et al. 2003). The cow urine and plant origin products have proved to be eco-friendly, residue free, bio-degradable, cost-effective and are known to impart resistance in plants against insect pests and diseases (Geetanjaly and Tiwari 2013).

As no systematic work on the management of mites using botanicals or plant extracts, indigeneous products, predators and safer acaricides has been carried out on hydroponic capsicum under protected cultivation in North India especially the state of Punjab, so the present studies were planned to evaluate these products against yellow mites. These studies can from a basis for developing an effective management strategy using biorational approaches. The natural plant products, indigeneous and natural products and safer molecules having different modes of action can be successfully used in pest management programmes thus founding a basis for an eco-friendly way of pest management especially under protected conditions.

Materials and methods

The present study on management of *P. latus* on hydroponic capsicum using indigenous methods or natural products and biorational approaches was undertaken in the polyhouse of Department of Soil and Water Engineering, and Acarology laboratory, Department of Entomology, Punjab Agricultural University, Ludhiana during 2019.

Preparation of natural products

The different biorationals including natural plant extracts i..e. PAU home made neem extract, *Dherek* extract, *Pongamia* extract, ginger extract, garlic extract and pepper extract and indigeneous products viz. *Agniastra, Brahamastra, Neemastra*, were prepared freshly. The composition and doses of these products is being presented in Table 1.

Evaluation of biorationals against mites on capsicum

Different biorationals including natural or indigeneous products and botanicals, along with chemical acaricide, propargite and spiromesifen was evaluated against yellow mite, *Polyphagotarsonemus latus* (Banks). The different

Table 1 Natural products/biorationals evaluated against mites on capsicum

Natural/ indigenous product	Composition and method of preparation	Dose (s), ml/l or %	Source /formulator
Cow urine and cow dung	cow urine and dung of Indian cow	Used for preparing different natural preparations	Dairy Farm, GADVASU, Ludhiana and School of Organic Farming, PAU, Ludhiana
PAU home made neem extract	4 Kg of neem (*Azadirachta indica*) leaves/stems/fruits boiled in 10 litres of water for 30 minutes and filtered with a double layered muslin cloth	8,10,12 ml/l	Department of Entomology, PAU, Ludhiana
Dherek extract	4 Kg of *dherek* (*Melia azadiracht)* leaves/stems boiled in 10 litres of water for 30 minutes and filtered with a double layered muslin cloth	8,10,12 ml/l	Department of Entomology, PAU, Ludhiana
Pongamia extract	4 Kg of *Pongamia* leaves/stems boiled in 10 litres of water for 30 minutes and filtered with a double layered muslin cloth	8,10,12 ml/l	Department of Entomology, PAU, Ludhiana
Neemastra	Neem leaves/tender shoots (5 Kg), cow urine (5 litres), cow dung (2 Kg) and water (100 litres). Mix all the ingredients and keep in open for 48 hours. Stir the mixture in clockwise direction 3 -4 times a day. Filter using a double layer muslin cloth.	30,40,50ml/l	Department of Entomology, PAU, Ludhiana
Brahamastra	*Desi* cow urine (20 litres), paste of neem leaves (2 Kg), paste of mango leaves 2 Kg), paste of guava leaves (2 Kg), paste of castor leaves (2 Kg), water (100 litres). Mix all the ingredients and boil for half an hour. Cool it and filter using a double layer muslin cloth.	30,40,50ml/l	Department of Entomology, PAU, Ludhiana
Agniastra	Green leaves of neem (5 Kg), Desi cow urine (20 litres), Tobacco powder (500gm), paste of pungent green chillies (500 g), paste of *desi* garlic (500 gm, water (200 litres). Mix all the ingredients and boil for half n hour. Cool it and filter using a double layered muslin cloth.	30,40,50ml/l	Department of Entomology, PAU, Ludhiana
Pepper extract	1, 2 and 3 kg of green pepper each grinded and dissolved in 100 litres of water respectively. Filtered in double layer of muslin	10,20,30ml/l	Department of Entomology, PAU, Ludhiana
Ginger extract	1, 2 and 3 kg each of fresh ginger grinded and dissolved in 100 litres of water respectively. Filtered in double layer of muslin	10,20,30ml/l	Department of Entomology, PAU, Ludhiana
Garlic extract	1, 2 and 3 kg each of garlic cloves with outer layer removed, grinded and dissolved in 100 litres of water respectively. Filtered in double layer of muslin	10,20,30ml/l	Department of Entomology, PAU, Ludhiana
Anthocorid*, Blaptostethus pallescens* (3rd instar nymphs)	The culture of *B. pallescens* was obtained from the Dr G S Kalkat Biocontrol Laboratory, PAU, Ludhiana.	5, 10,15	Department of Entomology, PAU, Ludhiana

treatments comprised of PAU home made neem extract, *dhrek* extract, *pongamia* extract, *neemastra, brahamastra, agniastra*, pepper extract, ginger extract, garlic extract, water spray and recommended propargite 57EC @ 200ml/acre and spiromesifen 22.9 SC @ 150ml/acre along with untreated control.

For evaluation of different biorationals against *P. latus* on capsicum, *Indra* hybrid was raised following recommended

agronomic practices in soil-less or hydroponic conditions. The experiment was laid out in randomized block design (RBD) with each of the concentration of biorational as one treatment and three replications were kept for all the treatments. Two sprays of treatments were given at weekly interval. First application of biorationals was done on October 29, 2019 at the appearance of 20-25 per cent mite infestation on plants and second application was given after one week. Observations were recorded from randomly selected three leaves each from top, middle and bottom canopies. These leaves were collected and brought to the laboratory. The number of mites (active stages) were recorded per leaf under stereozoom binocular microscope (Carl Zeiss Discovery V 8) at pre treatment, 1, 3, 5 and 7 days after each spray (DAS).

Statistical analysis The data were subjected to square root transformation and analyzed statistically for comparing treatments following Analysis of Variance (ANOVA) and the results were interpreted at 5 per cent level of significance.

Results

Evaluation of biorationals against capsicum under polyhouse conditions

The biorationals and natural products were tested under polyhouse conditions on hydroponic capsicum in October, 2019. The number of mites per leaf was counted before spray/release and the number of mites per leaf ranged from 14.75 to 18.75 mites/ leaf in different treatments. In addition, the effect of different treatments on phytotoxicity symptoms was also observed.

After first spray In the first spray, among all the treatments, most effective were found to be acaricides i.e. propargite and spiromesifen with number of mites being mean of 0.16 and 0.25 mites/leaf respectively (Table 2). In case of biorationals or botanicals, significant low mean number of mites was observed in pepper extract @ 30ml/l (0.22 mites/leaf) followed by garlic @ 30ml/l (0.33 mites/leaf) whereas ginger extract was found to be comparatively less effective in reducing the mite population as compared to pepper and garlic. The PAU home made neem extract and *pongamia* extract both at the highest doses of 12ml/l proved highly effective in reducing the mite population 7 DAS (1.00 and 0.58 mites/leaf respectively). Similarly, in case of natural products, *brahamastra, neemastra* and *agniastra* all at the highest dose of 50ml/l were found highly effective in reducing the mite population (0.50, 0.50 and 0.91 mites/leaf, respectively). However *dherek* extract was found inferior in reducing the mite population as compared to all the other treatments (Table 2). The bioagent, anthocorid bug, *B. pallescens* @ 10 nymphs /plant caused comparatively more mean reduction of mites (0.58mites/leaf). Even the water spray did not reduce the mite population much, whereas cow urine resulted in reducing the mite population to a great extent.

After second spray The second spray of all the natural products and botanicals was given after seven days of first spray. The mean mite population seven days after the second spray revealed significant reduction of mites in all the treatments with the trend similar to the first spray. In case of plots treated with pepper extract no mites were observed in the second spray while in ginger and garlic extracts also, the mite population recorded was very low (0.08 mites/leaf in both cases). Among the natural indigeneous products, *brahamastra, agniastra* significantly reduced the mite population to the range of 0.00 to 0.41 mites/leaf. *Dharek* extract was found to reduce the mite population at the end of the second spray, but seeing the overall results, it was comparatively less effective in controlling the mite population. Similar trend was seen for PAU home made neem extract and predator, *B. pallescens* after the second spray, where in significant reduction of mites was observed (Table 3).

Pooled mean of both sprays The mean number of mites of both the sprays in different treatments was pooled and it was observed that pepper extract, *brahamastra, neemastra,* and *agniastra* were found to significantly reduce the mite population and *dherek* extract was found comparatively less effective as compared to PAU home made neem extract and *pongamia* extract and urine treatments (Table 4).

Phytotoxicity

All the plots were observed for phytotoxicity symptoms in the form of yellowing, bronzing, wilting, if any. No phytotoxicity was observed in any treatment.

Discussion In this study we investigated the efficacy of various natural, indigeneous products and biorationals or plant products and safer molecules which can be incorporated into an integrated mite management programme against active stages of *P. latus* infesting hydroponic capsicum under polyhouse conditions. The present findings are in accordance with other studies (Reddy and Miller 2014; Raghavendra et al. 2017; Singh et al. 2018) wherein the evaluation of acaricides including spiromesifen and propargite was done and it was observed that spiromesifen and propargite significantly reduced the *T. urticae* population with higher mortality in spiromesifen after fourteen days of spray in cucumber, rose and okra respectively. In similarity to the present work, 100 per cent reduction of mites per leaf was observed in spiromesifen and 50-75 per cent mortality in neem products

Table 2 Efficacy of natural products and biorationals against *P.latus* on capsicum after first spray during 2019

Treatments	Dose (ml/l) or no./plant	Mean number of mites per leaf				
		1 DAS	3 DAS	5 DAS	7 DAS	Pooled mean of 1st spray
PAU Home made Neem extract	8	5.00 (2.43)	3.33 (2.08)	2.33 (1.82)	1.00 (1.38)	2.91
	10	1.67 (2.05)	2.33 (1.75)	1.67 (1.62)	0.00 (1.00)	1.41
	12	1.67 (1.55)	1.67 (1.58)	0.67 (1.24)	0.00 (1.00)	1.00
Dharek extract	8	3.33 (1.94)	4.00 (2.20)	3.67 (2.14)	3.00 (2.00)	3.50
	10	3.00 (1.99)	3.00 (1.95)	3.33 (2.08)	1.00 (1.38)	2.58
	12	2.33 (1.82)	2.00 (1.66)	1.33 (1.41)	0.67 (1.24)	1.58
Agniastra	30	0.67 (1.24)	1.67 (1.58)	1.33 (1.49)	1.00 (1.38)	1.16
	40	0.67 (1.24)	1.33 (1.47)	1.00 (1.38)	0.00 (1.00)	0.75
	50	1.00 (1.38)	1.00 (1.38)	0.00 (1.00)	0.00 (1.00)	0.50
Brahamastra	30	2.67 (1.79)	2.33 (1.80)	0.67 (1.24)	0.33 (1.14)	1.50
	40	1.67 (1.55)	0.67 (1.24)	0.67 (1.24)	0.67 (1.24)	0.92
	50	0.33 (1.14)	0.67 (1.24)	0.33 (1.14)	0.67 (1.24)	0.50
Neemastra	30	4.00 (2.23)	0.67 (1.24)	1.33 (1.47)	0.00 (1.00)	1.50
	40	5.33 (2.45)	1.33 (1.41)	1.00 (1.38)	0.00 (1.00)	1.91
	50	2.33 (1.75)	1.33 (1.49)	0.00 (1.00)	0.00 (1.00)	0.91
Pongamia extract	8	2.33 (1.75)	1.33 (1.47)	1.00 (1.33)	0.67 (1.24)	1.33
	10	1.00 (1.33)	1.00 (1.38)	0.67 (1.28)	0.00 (1.00)	0.66
	12	0.67 (1.28)	0.67 (1.24)	0.67 (1.24)	0.33 (1.14)	0.58
Ginger extract	1	3.67 (2.14)	1.67 (1.58)	0.67 (1.28)	0.00 (1.00)	1.50
	2	2.33 (1.75)	1.33 (1.52)	1.33 (1.48)	0.67 (1.24)	1.41
	3	1.00 (1.38)	2.00 (1.66)	2.00 (1.72)	0.00 (1.00)	1.25
Garlic extract	1	4.00 (2.19)	1.67 (1.55)	3.00 (1.90)	0.67 (1.24)	2.33
	2	0.67 (1.24)	0.00 (1.00)	1.00 (1.33)	0.00 (1.00)	0.41
	3	1.33 (1.47)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.33
Pepper extract	1	0.67 (1.24)	0.00 (1.00)	1.58 (1.00)	0.00 (1.00)	0.56
	2	0.33 (1.14)	0.00 (1.00)	0.00 (1.00)	0.67 (1.24)	0.25
	3	0.67 (1.24)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.22
Anthocorid, *Blaptostethus pallescens* (3^{rd} instar nymphs)	5 /plant	4.33 (2.13)	0.00 (1.00)	3.00 (1.90)	0.67 (1.24)	2.00
	10 / plant	1.00 (1.38)	0.00 (1.00)	1.33 (1.48)	0.00 (1.00)	0.58
	15 / plant	1.67 (1.58)	0.00 (1.00)	1.00 (1.38)	0.00 (1.00)	0.66
Urine	without dilution	4.33 (2.28)	1.67 (1.61)	0.67 (1.24)	0.00 (1.00)	1.66
Water spray	-	6.00 (2.62)	5.33 (2.36)	4.33 (2.23)	3.67 (2.15)	4.83
Propargite	1 ml	0.67 (1.24)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.16
Spiromesifen	1 ml	1.00 (1.33)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.25
Control	-	9.00 (3.14)	15.00 (4.00)	9.33 (3.20)	11.00 (3.45)	11.08
CD (p=0.05)		(0.88)	(0.73)	(0.66)	(0.40)	(0.66)

DAS days after spray

at seven days after spraying under polyhouse (Pathak 2016). Similarly, Roobakkumar et al. (2010) and Singh et al. (2018) reported that neem oil @ 4 per cent caused 58 per cent reduction in mite population three days after spray but mortality decreased to 46 per cent after seven days of spray, similar trend has been found in our study also. Neem, *Melia azedarach*, is constituted of different compounds which are mainly categorized under limonoids, triterpinoids and steroids (El-Wakeil 2013). The main active ingredient azadirachtin is a chemically complex compound synthesized as a secondary metabolite having wide array of acaricidal activity such as antifeedancce, fecundity deterrence, oviposition deterrence, growth inhibition, detrimental to physiological processes. Azadirachtin has the ability to modify or inhibit the moulting and juvenile hormone titres by acting upon the synthesis and release of prothoracic hormone and

Table 3 Efficacy of natural products and biorationals against *P.latus* on capsicum after second spray during 2019

Treatments	Dose (ml/l) or no./plant	Mean number of mites per leaf				
		1 DAS	3 DAS	5 DAS	7 DAS	Pooled mean of 2nd spray
PAU Home made Neem extract	8	0.33 (1.14)	0.67 (1.24)	0.00 (1.00)	0.00 (1.00)	0.25
	10	0.00 (1.00)	0.33 (1.14)	0.00 (1.00)	0.00 (1.00)	0.08
	12	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.67 (1.24)	0.16
Dharek extract	8	2.00 (1.66)	1.00 (1.33)	1.67 (1.48)	1.67 (1.58)	1.58
	10	0.67 (1.28)	1.67 (1.58)	1.00 (1.33)	1.67 (1.58)	1.25
	12	2.00 (1.66)	1.67 (1.55)	2.67 (1.91)	2.33 (1.82)	2.16
Agniastra	30	0.33 (1.14)	0.00 (1.00)	0.67 (1.28)	0.00 (1.00)	0.25
	40	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00
	50	0.00 (1.00)	0.67 (1.24)	0.00 (1.00)	0.67 (1.24)	0.33
Brahamastra	30	0.67 (1.24)	0.33 (1.14)	0.00 (1.00)	0.67 (1.24)	0.41
	40	0.00 (1.00)	0.33 (1.14)	0.00 (1.00)	0.00 (1.00)	0.11
	50	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.33 (1.14)	0.08
Neemastra	30	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.33 (1.14)	0.08
	40	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00
	50	0.00 (1.00)	0.67 (1.24)	0.00 (1.00)	0.00 (1.00)	0.22
Pongamia extract	8	0.67 (1.24)	0.67 (1.24)	0.00 (1.00)	1.00 (1.33)	0.58
	10	0.33 (1.14)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.11
	12	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.33 (1.14)	0.08
Ginger extract	1	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00
	2	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.33 (1.14)	0.08
	3	0.00 (1.00)	0.33 (1.14)	0.00 (1.00)	0.00 (1.00)	0.08
Garlic extract	1	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.33 (1.14)	0.60
	2	0.33 (1.14)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.11
	3	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00
Pepper extract	1	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00
	2	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00
	3	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00
Anthocorid, *Blaptostethus pallescens* (3rd instar nymphs)	5 /plant	0.00 (1.00)	0.00 (1.00)	1.33 (1.49)	0.33 (1.14)	0.41
	10 / plant	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00
	15 / plant	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00
Urine	without dilution	0.67 (1.24)	1.33 (1.52)	3.33 (2.08)	1.67 (1.62)	1.75
Water spray	-	2.33 (1.80)	3.33 (2.06)	2.67 (1.82)	3.67 (2.10)	3.00
Control		8.00 (2.99)	5.00 (2.23)	6.67 (2.72)	4.67 (2.34)	6.08
CD (p=0.05)		(0.37)	(0.53)	(0.41)	(0.45)	(0.44)

DAS days after spray

allatrotropins from the *corpus cardiacum* (Bezzar-Bendjazia et al. 2017) Azadirachtin acts as insect growth regulator thereby modifying the metamorphosis and also it exhibiting high levels of acaricidal activity derives support from the findings (Thakur and Sood 2017). From the above observations, it became clear that home made aqueous extract of neem fruit requires a higher concentration for pest management as compared to the commercial formulation. The categorization of *dherek* extract being moderately effective finds support from other observations of Bhullar et al. 2020 and Bezzar-Bendjazia et al. (2017), wherein they observed that *Melia azedarach* possess insecticidal, antifeedant, growth regulating and development modifying properties in a wide array of insect and mite pests. Not much literature is available on the evaluation of the natural products and cow urine on mites. The high acaricidal activity of *neemastra* and *agniastra* can be attributed to the added cow byproducts which as sole component offer high level of lethal toxicity to *T. urticae* adults (Bhullar et al. 2020; Phukan et al. 2017; Thakur and Sood 2017).

Table 4 Pooled means of two sprays on efficacy of natural products and biorationals against *P.latus* on capsicum during 2019

Treatments	Dose (ml/l) or no./plant	Mean number of mites per leaf				
		1 DAS	3 DAS	5 DAS	7 DAS	Pooled mean of 2 sprays
PAU Home made Neem extract	8	2.67	2.00	1.17	0.50	1.59
	10	0.84	1.33	0.84	0.00	0.75
	12	0.84	0.84	0.34	0.34	0.59
Dharek extract	8	2.67	2.50	2.67	2.34	2.55
	10	1.84	2.34	2.17	1.34	1.92
	12	2.17	1.84	2.00	1.50	1.88
Agniastra	30	0.50	0.84	1.00	0.50	0.71
	40	0.34	0.67	0.50	0.00	0.38
	50	0.50	0.84	0.00	0.34	0.42
Brahamastra	30	1.67	1.33	0.34	0.50	0.96
	40	0.84	0.50	0.34	0.39	0.52
	50	0.17	0.34	0.17	0.50	0.30
Neemastra	30	2.00	0.34	0.67	0.17	0.80
	40	2.67	0.67	0.50	0.00	0.96
	50	1.17	1.00	0.00	0.29	0.62
Pongamia extract	8	1.50	1.00	0.50	0.84	0.96
	10	0.67	0.50	0.34	0.25	0.44
	12	0.34	0.34	0.34	0.33	0.34
Ginger extract	1	0.50	1.00	1.00	0.00	0.63
	2	1.17	0.67	0.67	0.50	0.75
	3	1.84	1.00	0.34	0.00	0.80
Garlic extract	1	2.34	1.16	1.75	1.09	1.59
	2	0.83	0.00	0.00	0.06	0.22
	3	0.34	0.00	0.50	0.00	0.21
Pepper extract	1	0.34	0.00	0.79	0.00	0.28
	2	0.17	0.00	0.00	0.34	0.13
	3	0.34	0.00	0.00	2.83	0.79
Anthocorid, *Blaptostethus pallescens* (3rd instar nymphs)	5 /plant	2.17	0.00	2.17	0.50	1.21
	10 / plant	0.50	0.00	0.67	0.00	0.29
	15 / plant	0.84	0.00	0.50	0.00	0.34
Urine	without dilution	2.50	1.50	2.00	0.84	1.71
Water spray	-	4.17	4.33	3.50	3.67	3.92
Control		8.00	8.34	6.33	6.67	7.34
CD (p=0.05)		0.34	0.00	0.00	0.00	0.09

DAS days after spray

Kaur et al. (2017) carried out a study to determine the consumption rate of anthocorid bug, *Blaptostethus pallescens* and evaluated its predatory efficacy against two-spotted spider mite on brinjal both under laboratory and polyhouse. The results revealed that the maximum consumption rate by the predator was found to be high at the ratio of 1:50 (85.32 %) under laboratory conditions. During the studies, it was also observed that by increasing the time, the per cent consumption of spider mite, *T. urticae* by anthocorid predator was increased. Under polyhouse, all the ratios (10, 20 and 30 per plant) of anthocorid bug were found to be at par with one another in minimizing the population of mites on brinjal and this supports our findings wherein, anthocorid bugs have also caused significant per cent reduction of yellow mites. Therefore from the present studies, it can be concluded that all the biorationals tested were effective in reducing the yellow mite population and can form an integral part of integrated mite management programmes.

Conclusion

In conclusion, according to our findings of the present study, amongst the biorationals, botanicals showed promising results against *P.latus* on capsicum under protected conditions. However, maximum reduction of mites was observed in case of acaricides. The reasons may be that the natural products were prepared indigenously, so there were no added stabilizers which would have syngerized the activity of these products. Also, these products are perishable and the mite exposure to them is less. But still, these natural products can be incorporated into the integrated mite management programmes under protected conditions so as to reduce the pesticide load in the protected cultivation.

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Declarations

Competing interests The authors declare that they have no competing interests.

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